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ABSTRACT

This paper describes a distributed approach toward designing an Intelligent Tutoring System for the World Wide Web (WWW) at the University "Politehnica" of Bucharest (Romania). This approach was implemented in the EDIT Learning Environment and is defined by the following features: a WWW dedicated architecture, a distributed way of working both in the design and exploitation phases; reusability; a heuristic method to gather the needed information from all people involved in the project rather than from a limited number of experts; an integrated communication system; and cost effectiveness. Inter-human communication receives a great deal of attention, as it is an important speed up factor for the learning process. (MES)

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Designing a Web-based Distance Learning Environment based on an Intelligent Tutoring System

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Abstract: This paper describes a distributed approach towards designing an Intelligent Tutoring System for the WWW. This approach was implemented in the EDIT Learning Environment and is defined by several features as: a WWW dedicated architecture, a distributed way of working both in the design and exploitation phases, a heuristic method to gather the needed information from all people involved in the project rather than from a limited number of experts. Inter-human communication receives a great deal of attention, as it is an important speed up factor for the learning process.

1. Introduction

Classical Intelligent Tutoring Systems (ITS) are designed to support either the development of student's procedural knowledge by simulations or the development of conceptual knowledge by lectures and textbooks combined with answers to specific questions. Such systems usually do not support the acquisition of both procedural and conceptual knowledge.

This concept of ITS has to be changed when developing an ITS that use WWW as delivery vehicle for all the activities. The system has to be self-sufficient and complete (Brusilovsky et al. 1996), i.e. has to support the acquisition of both conceptual and procedural knowledge.

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The advantage WWW brings is that HTML documents can be viewed using common web-browsers and low cost computer equipment. This is a major usability plus, as students, teachers and developers can access them from all over the world, without significant expertise or training. There are several other benefits that come from using the WWW platform:

- The use of standard and highly supported developing languages (HTML, PERL, JAVA).
- Cost-effectiveness and reusability in developing the ITS.
- Unified platform for ITS researchers to compare and exchange research results.
- Domain independence (i.e. allows the ITS to function across multiple domains: academic, technical, industrial, etc.).
- Universality (i.e. the web based ITS can be accessed worldwide, offering the largest possible pool of data).

One of the main drawbacks of the classical ITS approach is isolating the students. This is wrong as it can lead to deadlocks and a slow training process. It also makes the training less attractive for the social human being. This is why an extended communication system (email + virtual classrooms) between students and tutors has to be developed. This way deadlocks never appear and learning process is faster. Cheating is out of question as different students have different sets of exercises and simulations. So the communication system may act as an individual student exercise assistant.

2. Theoretical background

The traditional design of an Intelligent Tutoring System entails several modules: the Domain Model (DM), the Expert Model (EM), the Instructional Model (IM) and the Student Model (SM).

The *Domain Model* in this implementation contains a list of domain concepts and an order relation that establishes the sequence in which concepts should be mastered. The DM is not distributed, but it is stored on a server (and possibly mirrored) from which it is made available to all users.

The *Expert Model* consists of a list of tasks and/or questions and possible answers along with the domain concepts needed for solving them. In this case the EM is distributed as each exercise or simulation comes with its own part of the EM designed by the author. This is made possible by an easy and powerful scripting language and a well-defined interface between the EM and the SM. This allow the author to establish the way the SM will be updated as a result of the student's actions.

The *Instructional Model* tries to diagnose the student's level of knowledge and uses this information to determine what teaching materials should be presented to the student. The diagnosis is done using the data stored in the SM and the feedback from the EM. The IM is also server-based and not distributed.

The *Student Model* is the key to adaptability as it stores up-to-date information about the student's goals, knowledge etc, which allows the IM to make its decisions. This implementation is a differential one, which focuses on the differences between the student and the EM, and resides on the main server, due to the need to keep an accurate and accessible track of student data. There are several sub-models that are being used for organizing this data:

- The *Domain Knowledge Model* (DKM) is a fuzzy subset of DM representing domain concepts mastered by the student.
- The *Knowledge Delivery Model* (KDM) is a fuzzy relation between domain concepts and teaching materials. This relations override those set in the IM and may be modified only by the direct tutor of the student.
- The *Knowledge Genesis Model* (KGM) is a fuzzy relation between domain concepts, which shows the necessity of other concepts before another. Like KDM this overrides the implicit settings in DM.

3. Pilot implementation

This ITS approach was implemented in the EDIT Learning Environment (ELE) developed by EDIL R&D Centre, University "Politehnica" of Bucharest within the project "Open and Distance Learning Network

in Information Technology and Microelectronics" (Drondoe et al. 1998, Voinea et al. 2000). The main characteristics of ELE are:

WWW dedicated architecture

The operation of ELE is based on the use of the WWW as the delivery vehicle for all the activities. The access is via a dedicated WWW-server (edit.pub.ro) using common web-browsers. The network structure integrates also a number of database servers distributed in the main centers of the EDIT Distance Learning Network.

Distributed way of working

Taking advantage of the opportunities provided by the WWW and in the spirit of interoperability principles a distributed way of working is promoted. Universally available libraries of teaching resources are used in order to provide instructional designers with the possibility to add, modify and delete materials. As a heuristic method to build the models specific to the ITS is used, every material that is published in the framework of the ITS has to undergo the evaluation of a certain number of Subject Matter Experts (SME) (Nielsen 1994). This will give the fuzzy relation between domain concepts and the teaching material enabling the inference engine to dynamically construct the recommendations for a specific student model.

Reusability

The WWW based architecture offers a high degree of reusability (architecture reusability). The general graphic interface is both domain and platform independent. The interface is also completely customizable by instructional designers. A new courseware is very easily translated in a form that ITS understands by specialized programs. They ask all necessary questions and perform all the heuristic evaluations to obtain the collection of necessary fuzzy models (DM, EM, and SM). Special tools have been developed to build new models using the concepts of the already existing domain models. New teaching materials regarding existing domains are automatically added to the libraries of teaching materials, the system taking care of the KDM update.

Heuristic approach brings ITS to college level expertise

For a long while ITS were the exclusive domains of high profile experts. This system tries to evade this confinement by replacing the expensive required expertise with the teaching community experience. Besides being cost effective, this method also provides much more realistic models that exhibit adaptive behavior when subjected to the real world. In order to create a teaching material the only prerequisite software is a word processor, an image editor and the basic Internet browser. There is no need for the SME team to understand the intimate internal knowledge representation scheme because the questionnaires are carefully designed (user transparent knowledge representation scheme) and this results in a major reduction of the development time.

Integrated communication system

This ITS has an extended communication system (email+virtual classrooms) between students and tutors taking part to the same training program. This way deadlocks never appear and learning process is faster. The communication system may act as individual student exercise assistant. It has been proved that an impersonal cyberspace does not help the intellectual development of the student. The human nature craves for social interaction and the paucity of communication leads to a stress that prevents the complete and thorough accumulation of knowledge and procedures.

Cost effectiveness

This ITS system's usability is reflected also in the low hardware and software resources it requires. The system has a client/server architecture. Both SME and students can work on machines that are readily available and cheap. These machines have all the needed software installed at the moment they are bought. The SME don't need special software to create and publish new learning materials. They may use their favorite text and image processors, so there is no need for additional training for SME. Also SME do not need to prepare materials for different computing systems because of the platform independence of this ITS. The only powerful machine needed is the server. The maintenance software for the server is freeware and the OS is either freeware or has quite an insignificant price.

4. Interface tools

The integrated web-based email system and the virtual classroms is servicing only the tutors and students involved in an ITS related training activity. The e-mail service is used to solve some of the communication needs regarding both the administrative problems and the exchange of information among students and tutors. The virtual classrooms allow students and tutors to meet at their convenient time and discuss aspects of the course that need more attention. Students can ask questions and they can meet even when the tutor is not available, but they can enter only in training program assigned classrooms. There exists the possibility to moderate the discussions and ban those who use the service inappropriately.

The online checking of tests and simulations is performed by server side programs that simultaneously update the DKM and allow IM to choose the best training material. Using this programs gives a very fine granularity (Woods et al. 1996).

The secure access to SM database allows tutors to supervise their students (Fig. 1). This way a particular student model may be tailored to fit exceptional needs that the implemented Fuzzy Logic Control System does not meet yet. Future development may bring a Learning Fuzzy Logic Control System, powered by an artificial intelligence engine, which infers future correction rules from tutor's tailoring actions.

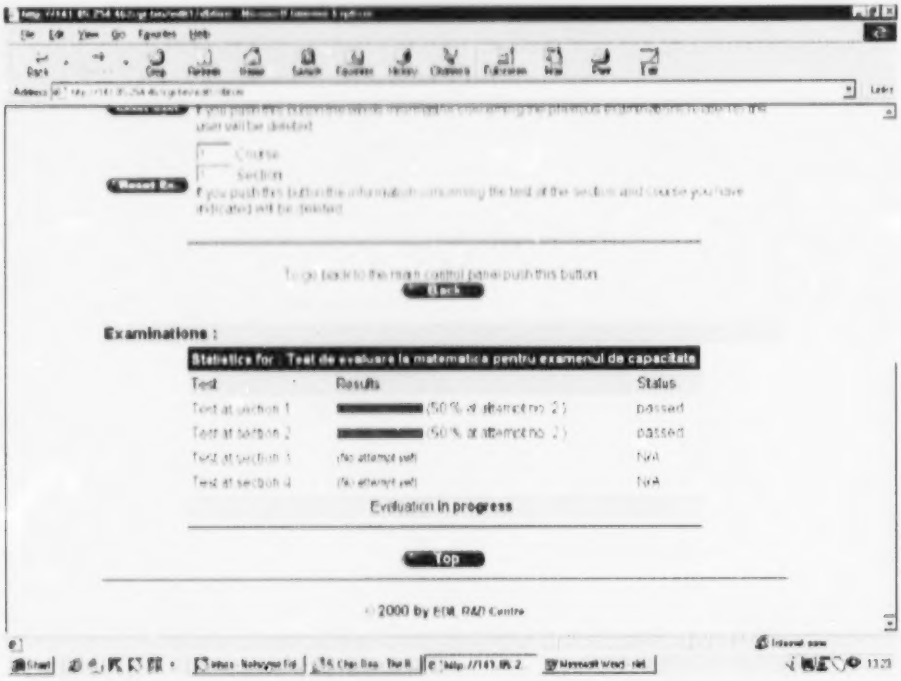

Figure 1: Screen snap shot of student tracking database

The publishing tools are very simple but on the other hand they can be very powerful and productive. As a matter of fact they are usual editing tools (text + image) + email programs + a set of rules the tutors have to follow. This ITS practically introduces only a set of rules. This way the work of experts is deeply structured. It does not take much intellectual efforts, therefore it does not cause subjective errors and gives good results in practical applications. A new course is to be submitted as a package and has to be realized in a fixed structure concerning file names. On the other hand it offers a large degree of freedom from the point of view of the pedagogical approach. Each course has to contain a file index.txt in which the names of the chapters and the corresponding sections are presented in form of a list. For each chapter a number of files must be provided.

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These files are:

- Explanatory files (with the name page_m_n.html where m is the chapter number and n the section number);
- Exercise pages (with the name ex_m_n_nr.html where m and n are the same as above and nr is the exercise number);
- Simulation pages (a pair of JAVA client/server applications with the name simc_m_n_nr.class & sims_m_n_nr. class). The applications for simulation pages are subject to a set of supplementary rules and are addressed to those who are familiar with the JAVA language. The images and JAVA applets used in the course must be included in the packet but they are not subject to a name pattern.
- Pre-test and post-test pages (with the name pretest_m.html and posttest_m. html where m is the chapter number)

In short, for a new course to be submitted it should have the following format:

Index.txt	Contents in list form
Pretest_m.html	Pre test page
Posttest_m.html	Post test page
Page_m_n.html	Explanatory pages
Ex_m_n_nr.html	Exercise pages
Simc_m_n_nr.class	Simulation pages
Sims_m_n_nr.class	
Images+applets	Images and applets used when writing the course

For submitting the new course all the files of the package are sent as email attachments to a certain address.

5. Modus operandi

When a new tutor applies for a position in a certain domain he has to obtain first the endorsement of the ITS site coordinator. For this, a tutor can access a position request form on the site home page. They have to fill in the required information and send it to the ITS site coordinator. If the request is approved, the tutor receives a login name and a password to get into the system. He has the right to make accounts for new students and supervise their performance.

When a new student applies for a training program it has to obtain first the endorsement of a tutor who is registered with the program specific domain. For this the student has to fill in a sign up request form he can find on the site home page.

When introducing a new domain, a SME must obtain first the endorsement of the ITS site coordinator by sending a domain request form. He has to specify the relationships between the new domain and the existing ones. If the request is approved, the domain will be automatically registered with the site and it will wait for new topics and courses.

When introducing a new topic in a domain, a SME must obtain first the endorsement of the domain tutors by sending a topic request form. He has to specify in the form the relationships between the new topic and the existing ones. If the SME obtains the endorsement of the majority tutors the new topic is automatically registered with the addressed domain.

When introducing a new course in a domain, a SME must obtain first the endorsement of the domain tutors by sending a course request form. If the SME obtains the endorsement of the majority tutors, he will receive an automatically generated password. The SME will use it in the subject line when sending the course as an email attachment to a given address. Server side programs will then generate the course format. The domain tutors will be the only ones to have access to it. They will approve or reject then each individual section of the course according to what the section claims it covers.

The system granularity with respect to the interaction control is extremely fine as it uses the accepted human-computer interaction principle of providing immediate feedback following every response from the user.

When a student joins an ITS system he is subjected to a pre-test that tries to asses the domain concepts and areas that need working on. After this the computer generates an optimum path for the education experience, that the student is about to undergo. Each section on the path consists of a loop:

```
Section{
        Pre- test ;
        Learning;
        Post-test;
         }
        until (Post-test > threshold);
```

where all the elements are dynamically generated, according to the student's profile.

The course is considered completed when the final post-test mark is greater than a given threshold. When a student uses the Help/Assistance/Modeling options for exercise solving, the SM is updated such that the better the student model fits the student the less assistance is needed during exercise solving.

6. Conclusions

A framework for developing generic ITS has been presented. No restrictive assumptions were made, so ITS in any domain can be created.

The heuristic method used to gather the needed information from all people involved in the project rather than from a limited number of experts significantly shortens the implementation time. The main benefit of this approach is that it brings the designing of ITS to a less scholarly level, making it available to educators and students without requiring additional expertise and thus opening up a greater potential developer space. This would result in vaster set of teaching resources available for the ITS DM and EM.

One breakthrough of this system is that it implements a distributed way of working. Tasks are distributed among the project team and volunteer developers. They are able to work without being in the same geographical area, and their work is automatically integrated within the system.

At the basis of this implementation lies the WWW dedicated architecture. This has allowed us to reach a high level of reusability (i.e. reusability of architectures) and also cost-effectiveness. This architecture has permitted us to have an intense inter-human communication that significantly speeds up the learning process.

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